Soil Crusts
of
Moses Coulee Area
Washington

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and Amanda Hardman
NW Lichenologists
2013-2014

Texosporium sancti-jacobi

Introduction

Biological soil crusts are a close association between soil particles and cyanobacteria, microfungi, algae, lichens and bryophytes (Belknap et al. 2001). They are known to be widespread across the arid lands of southern and western North America, where they reduce non-native plant invasion, aid in soil and water retention, reduce erosion and fix nitrogen, making this often growth-limiting nutrient available to the ecosystem (Belknap et al. 2001).

On the other hand, soil crusts are just beginning to be explored in the Pacific Northwest. The earliest surveys were at Horse Heaven Hills in south-central Washington (Ponzetti et al. 2007). Now several areas in central Oregon, from the Columbia River basin in the north to the Lakeview BLM District in south central Oregon (Miller et al. 2011, Root and McCune 2012, Stone, unpublished Lakeview BLM reports 2013 and 2014 and Malheur N. F. 2014), have been surveyed. The central area of Washington, which includes many acres of steppe habitat in channeled scablands created by the Missoula Floods, has not previously been surveyed. Much of this land has been grazed, and some small areas remain undisturbed or have been closed to grazing recently.

The purpose of this study was to survey intensively at sites with different levels of grazing activity, at different elevations, and in different habitats, in order to gain some understanding of what soil crust lichen and bryophyte species are present, the extent of the soil crusts, and the quality of different habitats. Since Northwest Lichenologists received the grant for this study, another purpose of the study was to gather knowledge from different soil crust experts and to share that knowledge with botanists who work in the area.

Methods

In 2013, we surveyed in the area between the towns and cities of Douglas, Wenatchee, Ephrata and Electric City. Eleven surveyors participated in the first season of field work, which took place from 20-25 September, 2013. In 2014, we surveyed an area slightly to the east, between the towns of Marlin, Wilbur and Davenport. Seven surveyors participated in the second season of field work, from 28 September through 1 October 2014 (Maps A-E). Each day we divided into small survey teams, each of which went to several locations, then convened at our camp each evening. During the 2013 survey we visited 10 locations, sampling 58 plots, and in 2014 we visited 7 locations, sampling 30 plots. Plots were chosen intuitively, typically with at least one lithosol and several other habitats at each location, with the goal of finding as many species as possible at each location (Root and McCune 2012). Many were paired sites with deep soils and shallow soils (lithosols). A list of sites, site locations, and basic vegetation is in Appendix 1. Surveyors were Daphne Stone, Amanda Hardman, Heather Root, Cecile Guiedan, Michael Russell, Jeanne Ponzetti, Molly Boyter, Pam Camp, Kathryn Beck, Scot Loring, Roger Rosentreter and Robert Smith in 2013. In 2014, surveyors were Daphne Stone, Amanda Hardman, Erica Heinlen, Scot Loring, Molly Boyter, Kim Frymire, and Pam Camp.

Fig. 1. 2014 Survey team, missing Molly Boyter and Pam Camp.

Specimens of nearly every species seen at each site were collected at the sites, bagged and labeled. Once we had an idea of the most common species, ones that were easily identified in the field were recorded but not always collected. Before identification, specimens were stabilized by gluing each soil clump to a card using a water/white glue mixture. When dry, a thick bead of glue was applied around the edge of the soil clumps on the cards to stabilize further. Specimens from 2013 were identified by Roger Rosentreter, Daphne Stone and Rob Smith. Specimens from 2014 were identified by Daphne Stone and Erica Heinlen. Voucher specimens were curated and a full voucher set was deposited at WTU (University of Washington Burke Museum). A second, not complete set was retained at Wenatchee BLM. Further specimens were kept by Scot Loring, Daphne Stone, Roger Rosentreter and Katherine Beck.

Lichen nomenclature follows the Checklist for the Lichen-forming, lichenicolous and Allied Fungi of north America version 20 (Esslinger 2015), except for several species for which there is no current expert willing to look at them (*Caloplaca* spp., *Scytinium* spp.). We often used McCune and Rosentreter (2007) to help determine the species. Moss

nomenclature follows Flora of North America (2002, 2014). Liverwort nomenclature follows Wagner (2013) and Doyle and Stotler (2006).

Before ordination analysis, we consolidated the 2 years' data, lumped all *Grimmia* and lumped all *Encalypta*. Removing rare species (those occurring in less than 5% of sites) did not improve relationships, so all species were retained for subsequent analyses. Removing sites that were multivariate outliers did not improve relationships, so these were retained. Separate analyses for bryophytes and lichens did not improve interpretation, so these were analyzed jointly. We distilled the dominant vegetation types to four categories (*Artemisia tridentata* var. *wyomingensis, A. tridentata* var. *tridentata, A. rigida* and grasses) for further testing.

We ordinated sites using Nonmetric Multidimensional Scaling (NMS) ordination in PC-ORD version 7. For this, we used Sørenson distances, step-down dimensionality starting from 3 dimensions, 500 iterations, 200 runs with real data, 99 runs with randomized data, penalized ties, and the final solution rotated to principal axes. The final solution was 3-dimensional and had stress = 18.5%, which is moderate to somewhat high.

Results and Discussion

One hundred thirty two species were found during our surveys, of which one hundred eight were lichens. Twenty four bryophytes were found, including two hepatics and twenty two mosses. Site names with location, elevation, vegetation type and surveyors are listed in Appendix 1. Species and the plots where they were found are listed in Appendix 2.

Sites varied widely in the number of soil crust species they supported (Fig. 2, Appendix 2), from 3 to 47 species. For some sites, the reason for low diversity was clear; several of these were Conservation Reserve Program (CRP) sites that had been planted recently. Others with low diversity appeared to have soil that was not stable enough to support slow-growing species. Several sites appeared to have been heavily grazed in the recent past, and at least one site showed signs of wildfire.

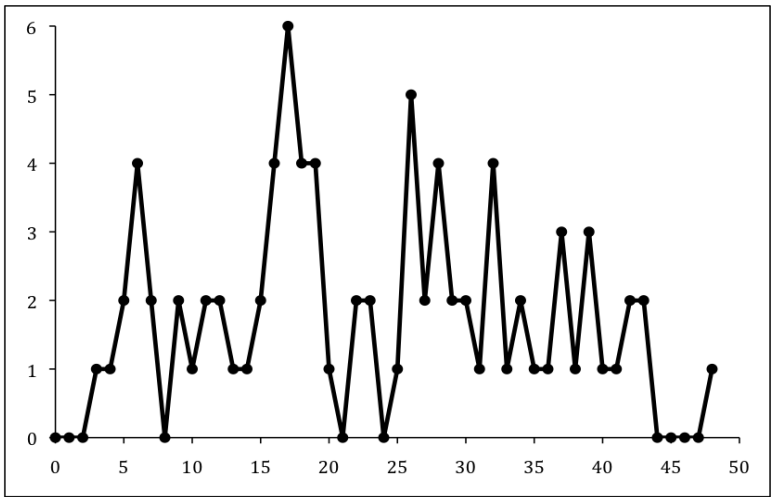

Fig. 2. Number of plots that contained each set number of species.

It is less obvious why some sites had high diversity. In general, lithosols had higher diversity than sites with deeper soils and *Artemisia tridentata* ssp. *wyomingensis*, but soil depth was not the only factor that created optimal soil crust habitat. The plot with the highest number of species was Airplane Canyon summit, which is remote and ungrazed. Some other plots with high diversity also were ungrazed but for some we do not have the grazing history.

We hypothesized that different survey localities may have had differences in the total number of species present, for instance the Duffy locality versus the Coal Coulee locality. We grouped plots by locality, then totaled the species found in all of the plots there (Fig. 3). On the same graph, we show the number of species found on the plot with the most species in that locality. Although the numbers are not completely comparable due to differences in number of plots in each locality and therefore not tested for significance, the graph shows an interesting pattern. The three collection localities on the left side of the graph were those with only one or two plots, explaining why the locality total is nearly the same as the highest number of species on one plot. However, to the right of those plots, the total number of species in the locality continues to rise, yet the maximum number of species found at any one plot levels off at around 40 species. The rising total number of species probably reflects additional habitats found on the aggregated collection of plots from the locality.

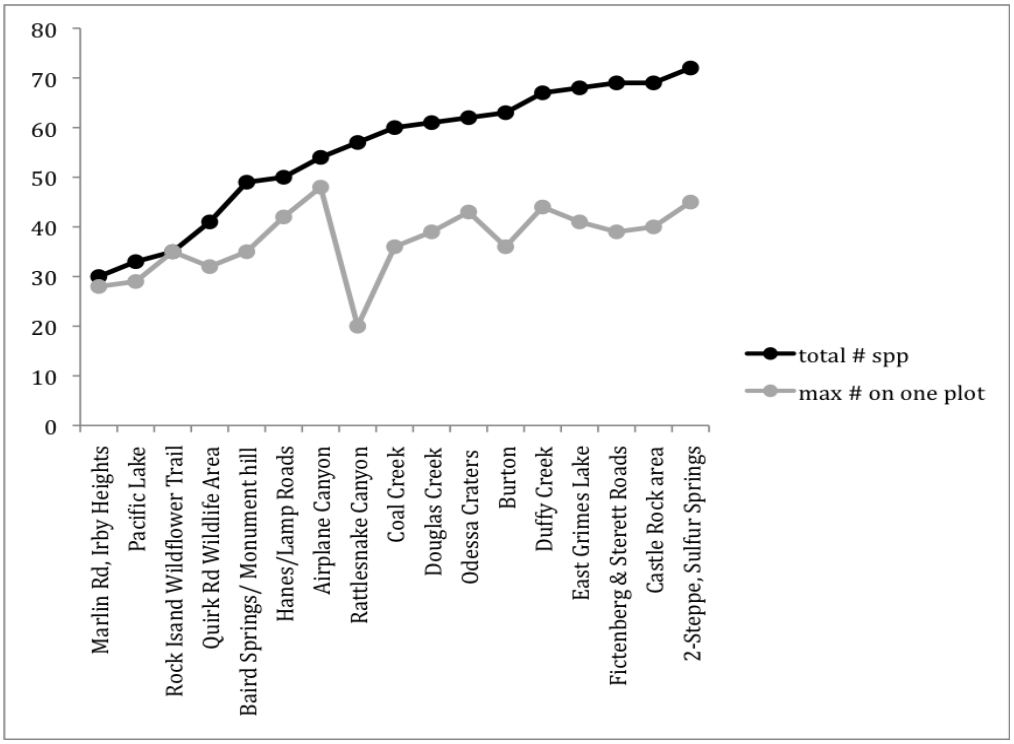

Figure 3. Surveyed plots were grouped into localities. The total number of species found in that locality is shown in black, and the maximum number of species on any one plot is shown in gray.

Ordination of Plots

Before ordination, we consolidated the data as described above. For ordination, 145 lichen and bryophyte taxa were used, in 84 sites. This number differs from the actual number of species reported above because it includes unidentified species in several genera and does not lump species that were later lumped because of identification problems such as Grimmia spp. and Encalpta spp. Average site richness was 22.6 species per site. Beta-diversity was moderate (Whittaker's diversity=5.4, half-changes=1.6).

The three axes explained 80.7% of the variation in the original community data, which indicates our axes caught most of the variation in community composition. Longitude, latitude and elevation did not have very strong correlations with the ordination scores (all correlations < 0.40), probably because observations did not cover a very large range of these variables. From examination of graphical overlays, there were no strong nonlinear relationships with these variables. However, there were suggestive patterns in community composition related to lithosols and vegetation types. For example, lithosol sites tended to be central on NMS axis 1 and low on NMS axis 2 (Fig. 4).

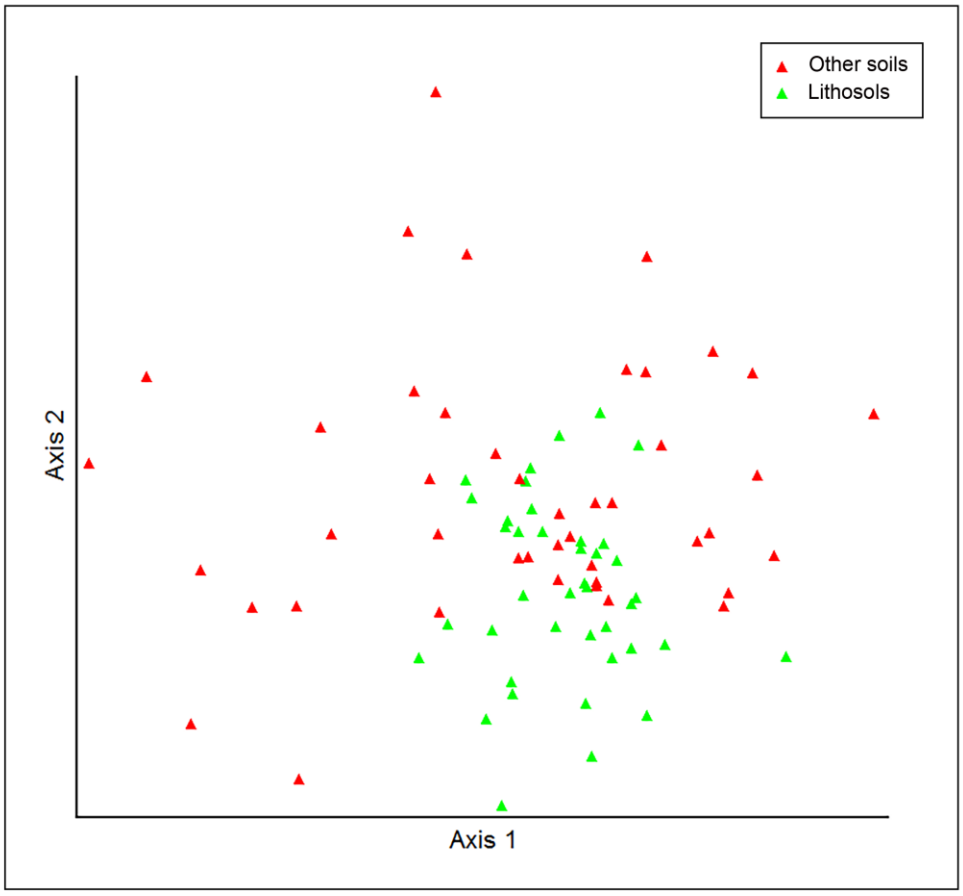

Fig. 4. Ordination of 2013 and 2014 plots. Lithosols are low and Axis 2 and central on Axis 1.

Plots in other vegetation types did not group tightly in the ordination, suggesting that soil crust species growing here were highly varied and dependent on other variables than vegetation type (Fig. 5).

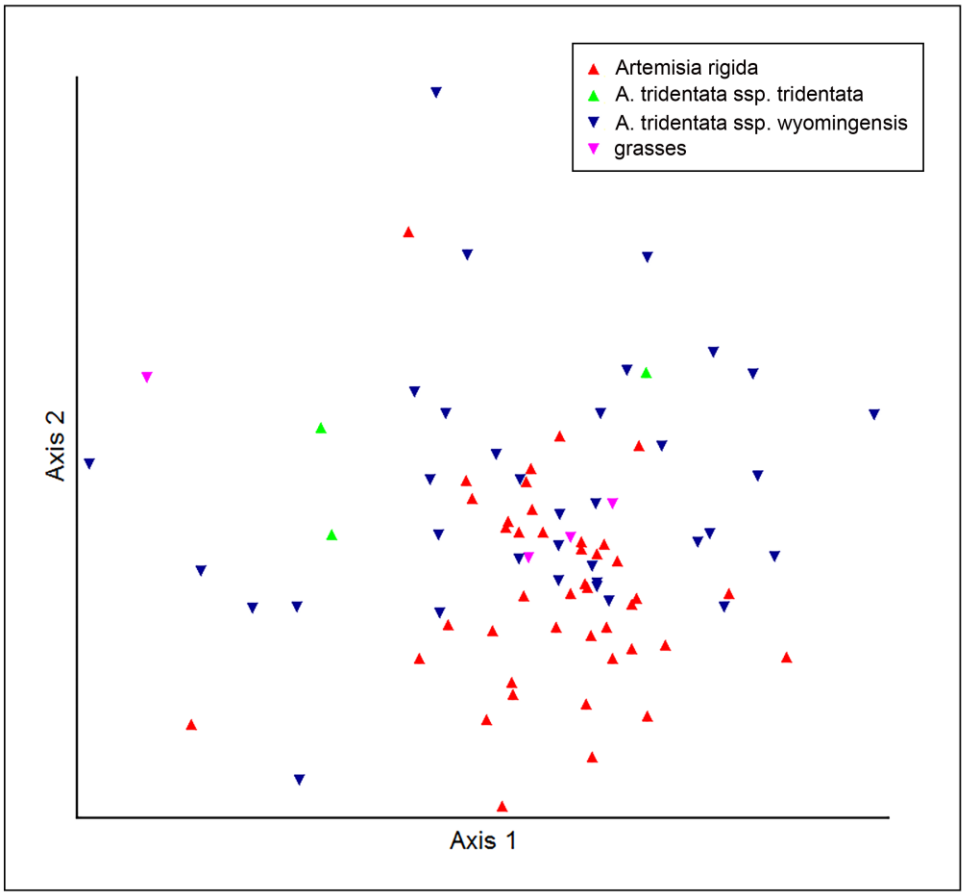

Fig. 5. The same ordination as Fig. 4, but with plots colored by vegetation type. *Artemisia rigida* is typical vegetation on lithosols.

We formally tested these relationships with Multi-response Permutation Procedures (MRPP). We used MRPP in PC-ORD 7 to test for differences in cryptogam community composition according to these categories: lithosol status, cowpie presence, and membership in one of the four dominant vegetation types (*Artemisia tridentata* var. *wyomingensis*, *A. tridentata* var. *tridentata*, *A. rigida* and grasses). Community composition differed significantly according to lithosol status ($A = 0.02$, $p << 0.001$). Community composition also differed significantly according to vegetation type ($A = 0.02$, $p << 0.001$): the predominant difference was between *Artemisia rigida* and all other groups, reinforcing the relationships with lithosol status (Fig.5). Community composition did not differ significantly according to cowpie presence ($A = -0.00003$, $p =$

0.45). Root and McCune (2012) also found that community composition was less tied to their measure of soil disturbance (abundance of cow dung), than to vegetation.

Indicator Species Analysis in PC-ORD 7 revealed no significant lichen or bryophyte indicator species for sites with cowpie presence, and only a smattering of barely interpretable indicator species for sites grouped by dominant vegetation types. However, there were 27 significant ($p < 0.05$) indicator species of lithosol sites. Some of the species with highest lithosol indicator values (*IndVal* > 60%) included*: Syntrichia ruralis, Amandinea punctata, Ceratodon purpureus, Diploschistes muscorum, Leptochidium albociliatum, Scytinium intermedium (sensu* McCune and Rosentreter*), Encalytpa* spp.*, Caloplaca stillicidiorum, Psora cerebriformis, Aspicilia filiformis,* and *Acarospora schleicheri.* Of the lichens on this list, all except for *Aspicilia filiformis, Caloplaca stillicidiorum* and *Psora cerebriformis* were considered Crust Indicator Species by Ponzetti (2007).

Hints at Succession

By examining species lists from highly disturbed sites and comparing them to less disturbed sites, we may be able to see the succession of species in time. The first species to colonize bare soil appear to be *Ceratodon purpureus, Gemmabryum caespiticium* and *Scytinium* spp. At Douglas Weedy Slope, an apparently very disturbed site with much invasive plant cover, only mosses were present. Grimes Lake NE had only 3 mosses and one lichen. Duffy 3 with *Artemisia tridentata* had 2 mosses, *Scytinium* spp. and *Cladonia* squamules. Duffy 1 had *Cephaloziella divaricata,* mosses, *Cladonia* squamules and *Psora montana.* Other sites with low diversity had mostly macrolichens and mosses, with few crustose lichen species. Without information about grazing and fire impacts on these plots, we can not say for sure if the macrolichens are early colonizers or are in habitats that are more conducive to them than crustose lichens.

Once mosses, *Scytinium* and *Cladonia* species have colonized, other species begin to appear. *Arthonia glebosa, Buellia* spp., *Cephaloziella divaricata, Collema tenax, Massalongia carnosa* and *Placynthiella* spp. begin to appear. Later-appearing species are *Aspicilia spp., Endocarpon* spp., *Lecanora* spp., *Phaeorrhiza* spp.*, Polychidium muscicola, Psora* spp.*, Placidium* spp.*, Rinodina* spp. and *Trapeliopsis* spp. *Diploschistes muscorum* that begins to appear on *Cladonia* thalli, and then on long-undisturbed plots, is in turn colonized by *Acarospora schleicheri* and *Rhizoplaca diploschistidina.* As the sites mature, differences in microhabitats promote different species. Further work on soil crust succession, using exclusions and sequential photography in several locations would help to understand the actual timelines and sequences of species appearance in the steppes of Washington.

Cowpies as Indication of Disturbance

In 2014 we recorded presence or absence of cowpies, as an indicator of past grazing. We compared the number of sites with cowpies vs. those without cowpies, on which each species was found. For most species, there did not appear to be a difference. However, out of the species that appeared more than four times, twenty one species appeared at

least twice as often on plots without cowpies than those with cowpies, and four appeared at least twice as often on cowpie plots (Fig. 6). These data are not useable for statistical comparison, but they may give us hints as to what species to investigate in future, in relation to grazing. Especially of interest is that all but one of the mosses found in 2014 appeared to thrive in plots without cowpies, including species found less than four times total. The only moss that did not fall into this pattern was *Polytrichum piliferum*, which was found on 9 plots of 30 total. This pattern could indicate that either the soil chemistry is changed by grazing, the soil is disturbed by trampling, or the places where cattle graze are worse habitat for mosses.

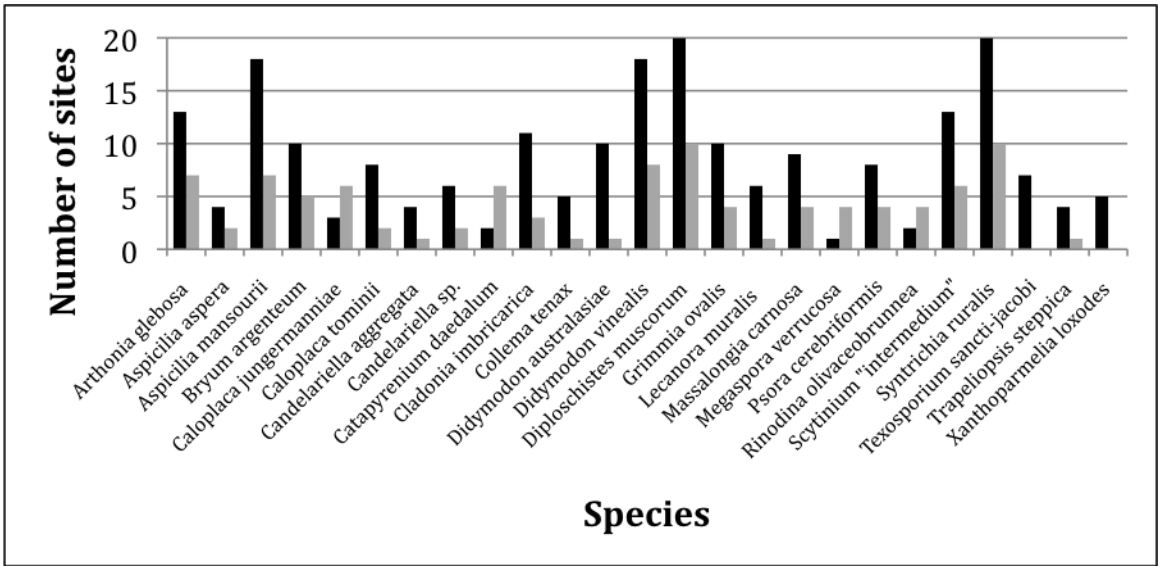

Fig. 6. Comparison of number of plots with cowpies (grey bars) to those without cowpies (black bars) on which some speices in the study were found. Only species found more than twice as often either on cowpie plots or on non-pie plots included.

Ponzetti (2007) interpreted resilience of the soil crust after fire in part due to high moss cover. DeBolt (2008) suggests that *Syntrichia ruralis*, the most common soil crust moss in the area, likely plays an important functional role in the hydrological cycle. Our finding of mosses inhabiting plots with cowpies less than plots without cowpies indicates that mosses may be equally vulnerable to trampling as lichens. Mosses may not be preceding lichens in reestablishing in disturbed areas. Some mosses tend to establish under cover of *Artemisia* (DeBolt 2007, Stone, pers. obs.) (Fig. 7), while others colonize tiny shaded areas on the sides of soil pinnacles. Perhaps mosses and lichens reestablish simultaneously, but in different microhabitats. Since mosses quickly grow larger, it could appear that they precede the lichens. Ponzetti (2007) also noted that fire-damaged mosses regenerated from the gametophyte bases. This could account for moss patches remaining large and regenerating more quickly than crustose lichens in burned areas.

Fig 7. showing *Syntrichia ruralis* thick under *Artemisia* sp. at Odessa Craters.

Four species appeared to grow more often on grazed plots, *Catapyrenium daedaleum, Caloplaca jungermanniae, Megaspora verrucosa* and *Rinodina olivaceobrunnea*. The latter three of these species grow on dead grass stubble instead of soil. Grazing likely promotes this habitat.

Our results are consistent with other studies which found a lack of relationship between cow dung and soil crust species (Root & McCune 2012, Ponzetti 2001). Several problems make this kind of analysis difficult. First, although grazing records may be accurate for an area, cattle do not graze evenly across the landscape. While cow pies may be present, they are not an accurate measure of grazing intensity. Second, steppe grasslands are made of many microhabitats, and differences in these microhabitats are as important to colonization as habitat on a larger scale.

Comparison to other studies

Soil crusts have been explored in south-central Washington (Horse Heaven Hills, Ponzetti et al., 2003) and several areas in central Oregon, from the Columbia River basin in the north to the Lakeview BLM District in south central Oregon (Miller et al. 2011; Root and McCune 2012; unpublished Lakeview BLM Reports, Stone Ecosurveys 2013

and 2014; Smith and Rausch 2015, unpublished Malheur Co. BLM Reports DeBolt 2008, 2010).

Comparing species lists from these studies presents some problems: some of the research focused on lichens, without collecting bryophytes; some lists include only those species found more than once; some studies were small in scope while others covered many acres; plot size varies from open-ended to large and defined to small and defined; and species concepts have changed in recent years as more work is being carried out in these arid areas. However, comparison of the species lists from these studies merits study. Species found in all studies include *Amandinea punctata, Arthonia glebosa, Caloplaca tominii, Collema tenax, Phaeorrhiza sareptana* and *Psora cerebriformis* (Table 1). These species are common in the Moses Coulee area. Species found in more than half of the plots also were all found in the Moses Coulee area.

Species that were found in less than half of the studies fall into several categories. Some are likely species for which the nomenclature has changed or misidentifications. One example is species in the genus *Aspicilia*. These species are difficult to distinguish, and will likely be extensively reorganized by research done by McCune and Di Meglio (unpublished study in progress). In other genera, some species are small and difficult to identify, so possibly they are represented on the list several times. Others are typically on wood or rock but have fallen off of their usual substrate. However, two categories are of interest, those that are easy to identify and those that are uncommon or rare.

Species that are easy to identify but found on less than half of the studies include the calciphiles *Circinaria hispida, Circinaria rogeri, Heppia lutosa, Psora tuckermanii* and *P. decipiens.* Of these five calciphiles, we found *H. lutosa* and *P. tuckermanii*. Five *Cladonia* species, although they are large, were found in less than half of the studies. We found most of these species, and a total of 8 *Cladonia* species total. *Cladonia cariosa*, found only in two studies often makes no podetia, so although the presence is known, the species is not. *Cladonia imbricarica* is very common in the Moses Coulee area, but earlier studies may not have been aware of the existence of the species or how to identify it. Several vagrant species of *Dermatocarpon* and *Xanthoparmelia* also fall into the category of having been found on less that half of the studies. The habitat for these species is a specific habitat within some lithosols where the soil surface is paved with small rocks or pebbles. For instance in the Moses Coulee study we found this type of paved lithosol at Airplane Canyon Odessa Craters, the Duffy Creek area, Grimes Lake area, Osbourne Heights, and Sterett Rd. S. *Rhizocarpon diploschistidina* and *Texosporium sancti-jacobi* are easily identified but were found on 4 plots or less. Their habitats should be studied and better defined so that we are able to find and protect them.

State-Listed Species

The Washington state sensitive species *Texosporium sancti-jacobi* was found on a cluster of plots including Odessa Craters (Fig. 8), Cache Craters, Coal Coulee and Pacific Lake. The sites where it was found were on fine *A. rigida* lithosols, and there was no evidence of grazing at these sites. List of locations is provided in Table 2.

Fig. 8. Photo of *Texosporium sancti-jacobi* (center) in a well-developed soil crust habitat.

Texosporium locations, Moses Coulee area 2014				
plot	**lat**	**long**		
Cache Crater 3	47.42134	-118.69745	approx	Diploschistes muscorum, Peltigera ponojensis, Leptochidium albociliatum, Cladonia fimbriata, Aspicilia filiformis, Cephaloziella divaricata, Ceratodon purpureus, Syntrichia ruralis
Coal Coulee E 2	47.36256	-118.43964	approx	Diploschistes muscorum, Ceratodon purpureus, Acarospora schleicheri, Peltigera ponojesis, Psora montana, Aspicilia filiformis
Coal Coulee N 1	47.366815	-118.45525	exact	Diploschistes muscorum, Cal stillicidiorum, Arthonia glebosa, Buellia punctata, Peltigera didactyla, Leptochidium albociliatum, Cladonia fimbriata
Coal Creek S 2	47.36584	-118.45311	approx	Diploschistes muscorum, Syntrichia ruralis, Gemmabryum caespiticium, Ceratodon purpureus
Odessa Craters 2	47.421858	-118.688198	approx	Diploschistes muscorum, Syntrichia ruralis, Ceratodon purpureus, several Cladonia spp., Caloplaca tominii, Art gleb, Gemmabryum caespiticium
Odessa Craters 3	47.421593	-118.68362	approx	Diploschistes muscorum, Buellia punctata, Arthonia glebosa, Acarospora schleicheri, Caloplaca tominii, Syntrichia ruralis, Ceratodon purpureus, Gemmabryum caespiticium
Pacific Lake N	47.4143	-118.72942	exact	Diploschistes muscorum, Ceratodon purpureus, Syntrichia ruralis, Cephaloziella divaricata

Table 2. Locations of *Texosporium sancti-jacobi* found during surveys.

Acknowledgements
This study was funded by an Interagency Special Status/Sensitive Species (ISSSSP) grant to Northwest Lichenologists. Many thanks to the ISSSSP for their interest in soil crust species, and providing us with funding to complete a study of this size. Heather Root and Roger Rosentreter taught us all much about what we were seeing in the steppe country. Many thanks to Botanists Molly Boyter and Kim Frymire of the Bureau of Land Management, who pointed us to the sites we visited, and accompanied us to some of them. Finally, thank you to all of the people who helped collect and curate the collections - all of the field crew and Lin Kyan.

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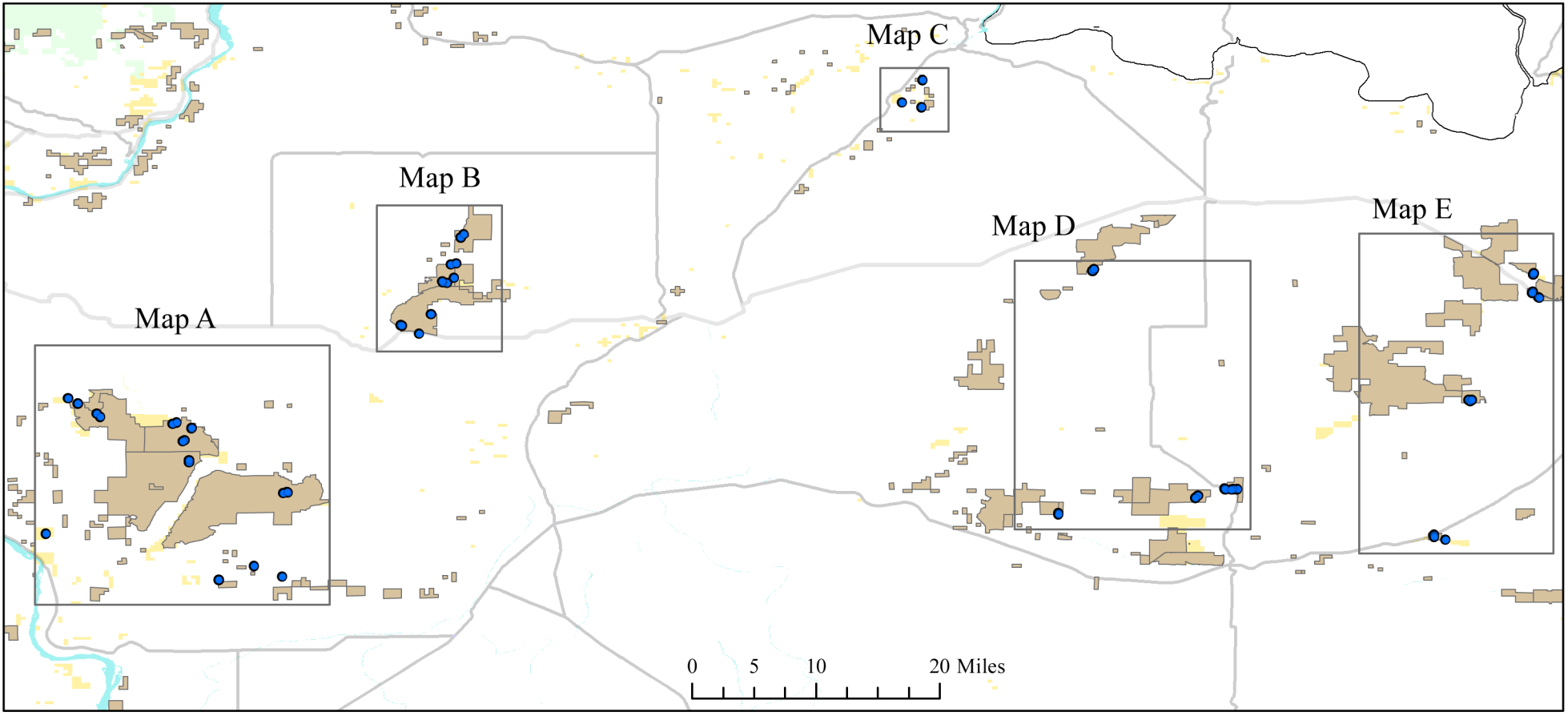
Spokane District BLM Biological Soil Crust Survey Plot Locations
Northwest Lichenologists 2013-2014

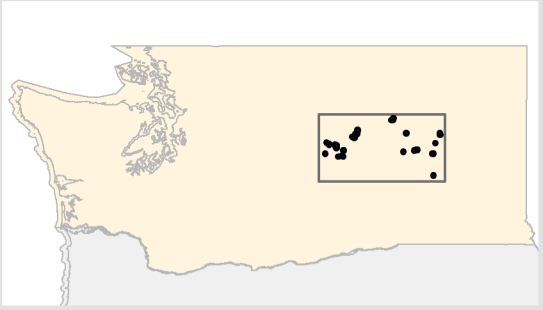


Legend

Allotments

Plots

Project Area within Washington



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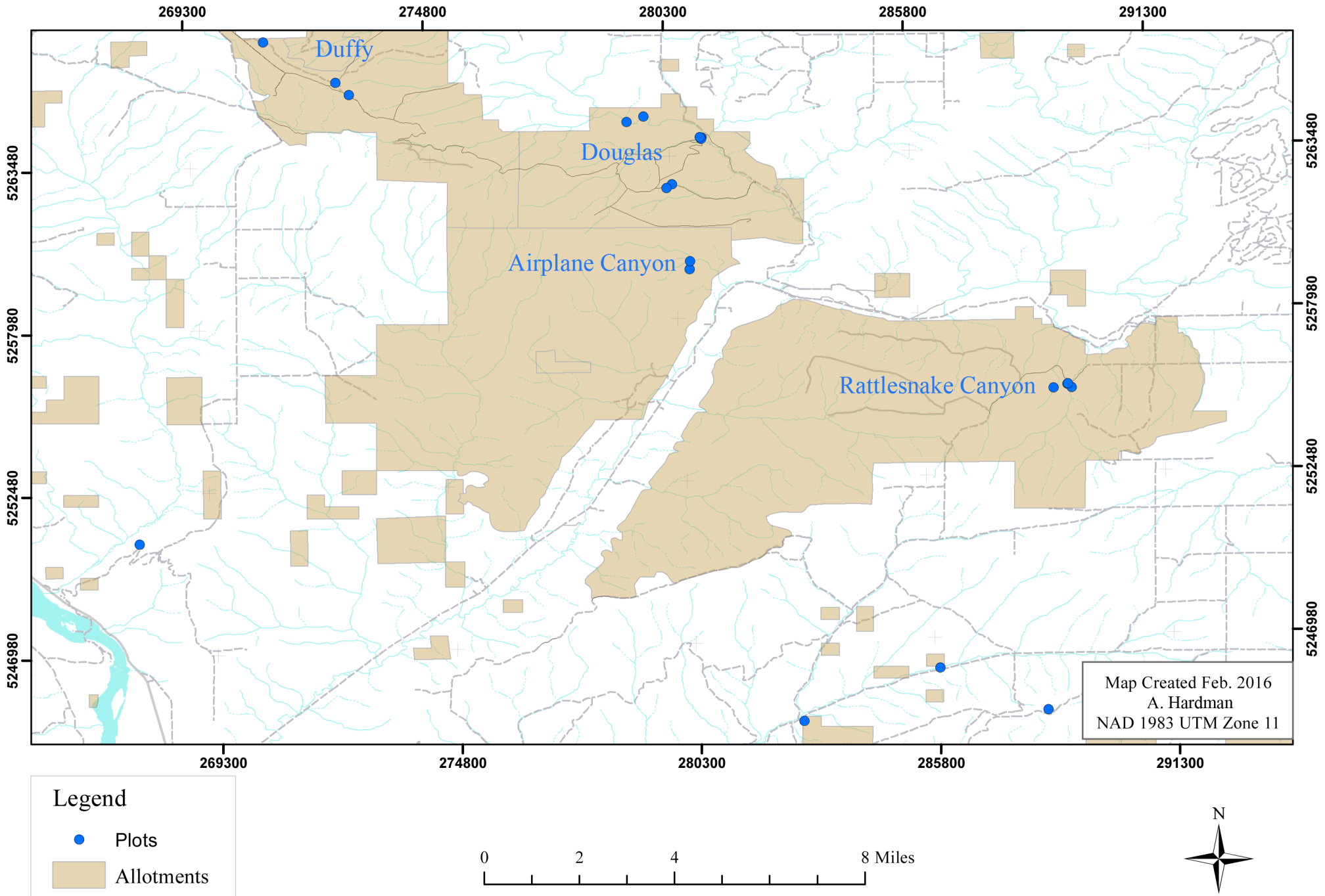
Map created February 2016
A. Hardman

Map A plot locations



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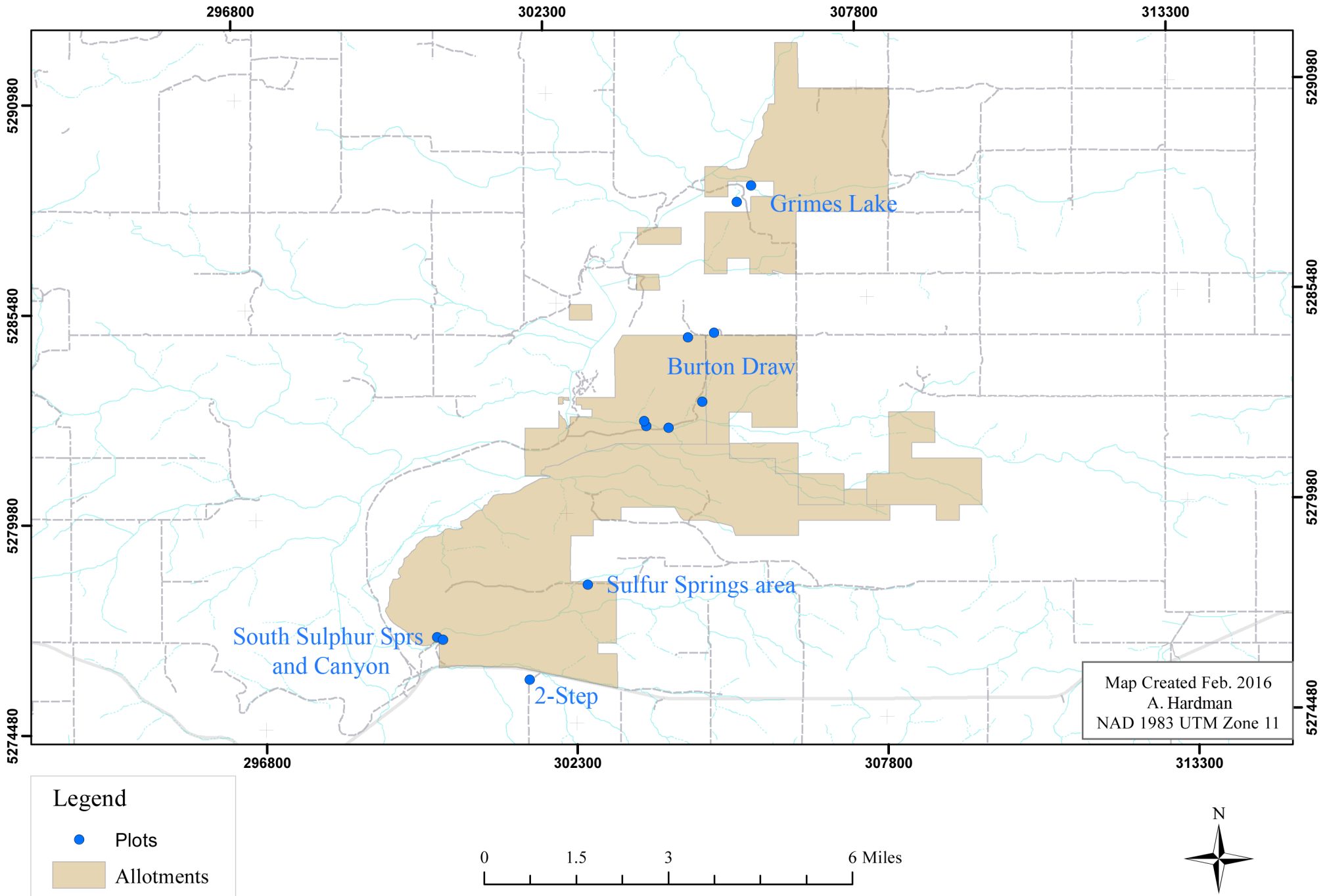

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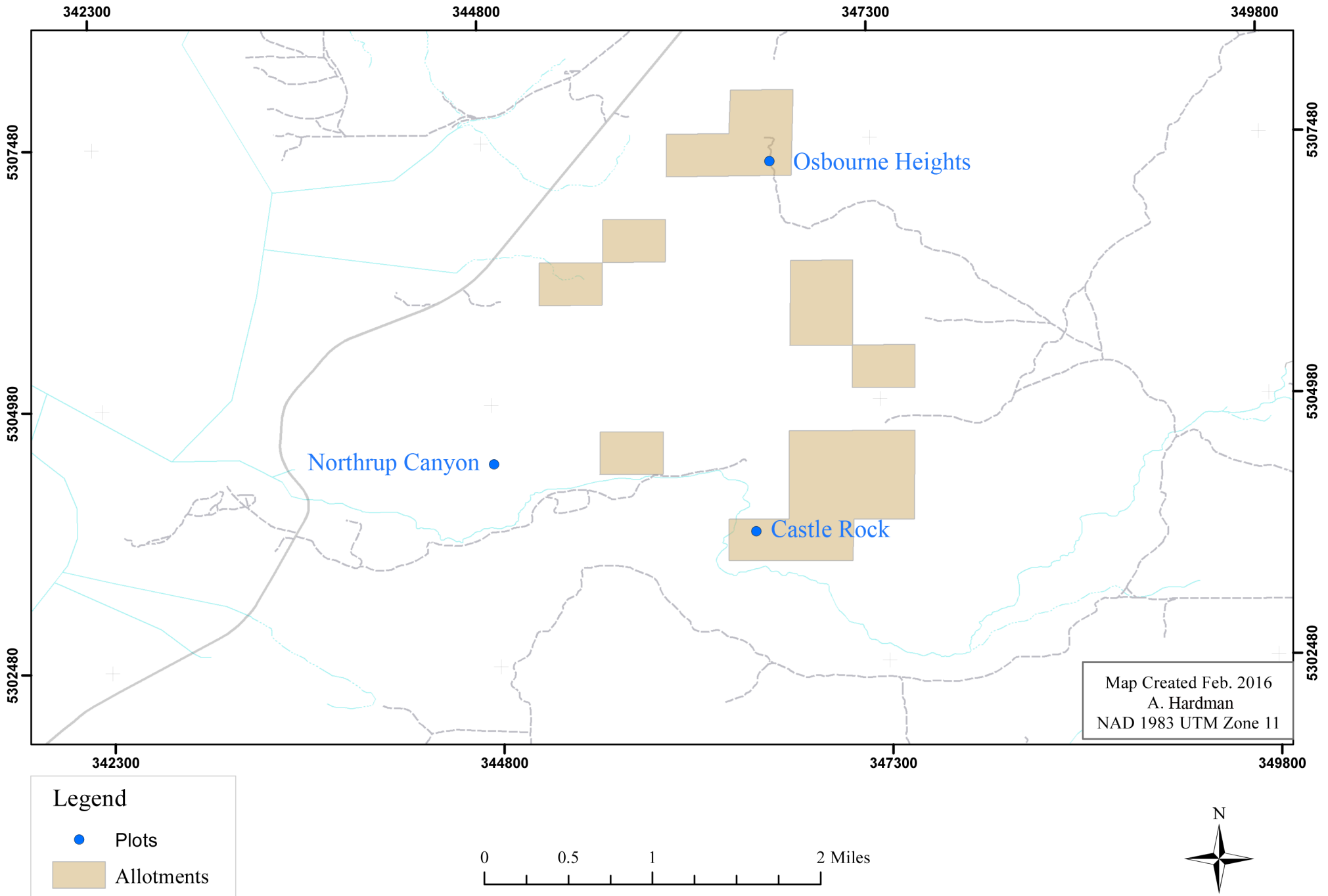

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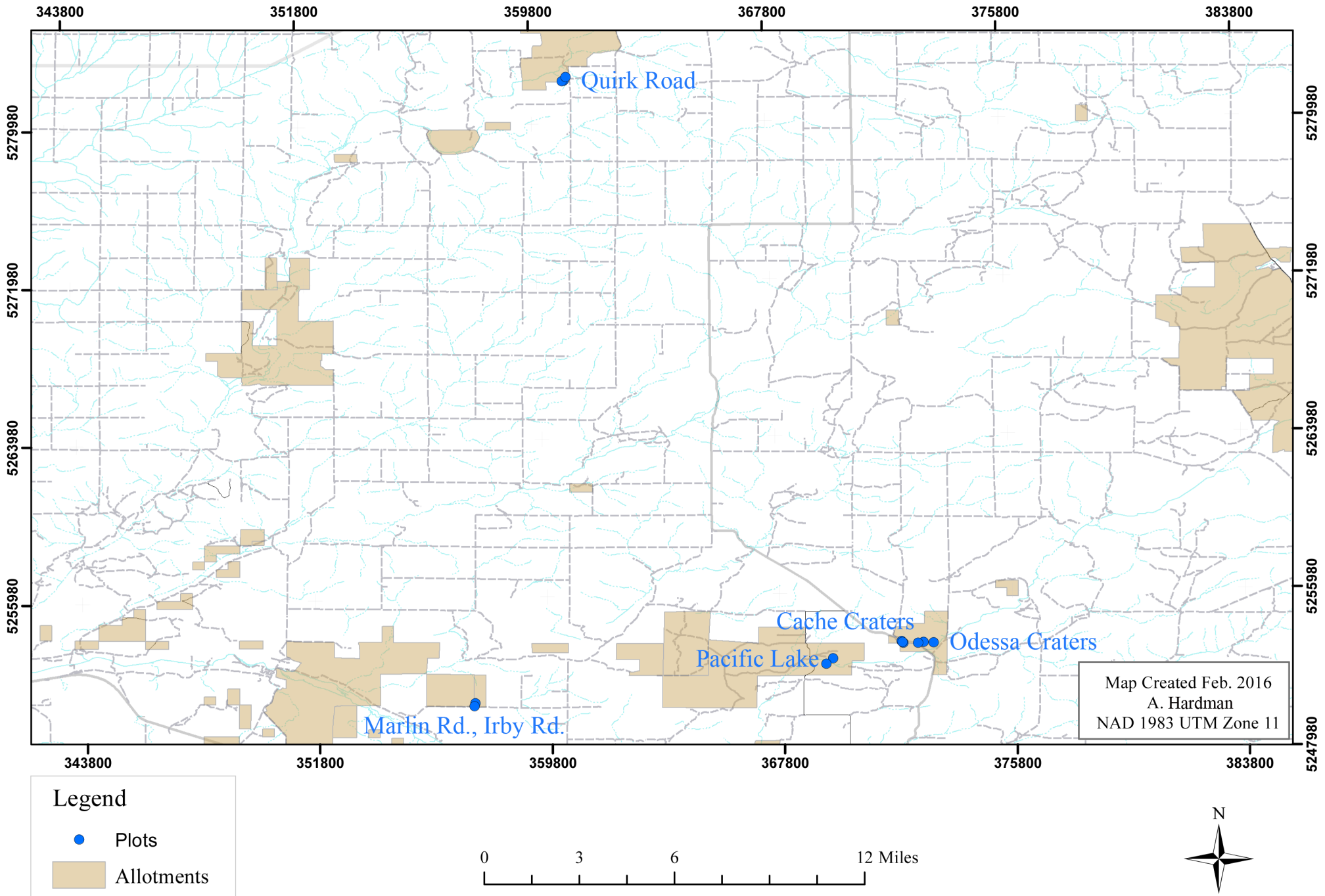
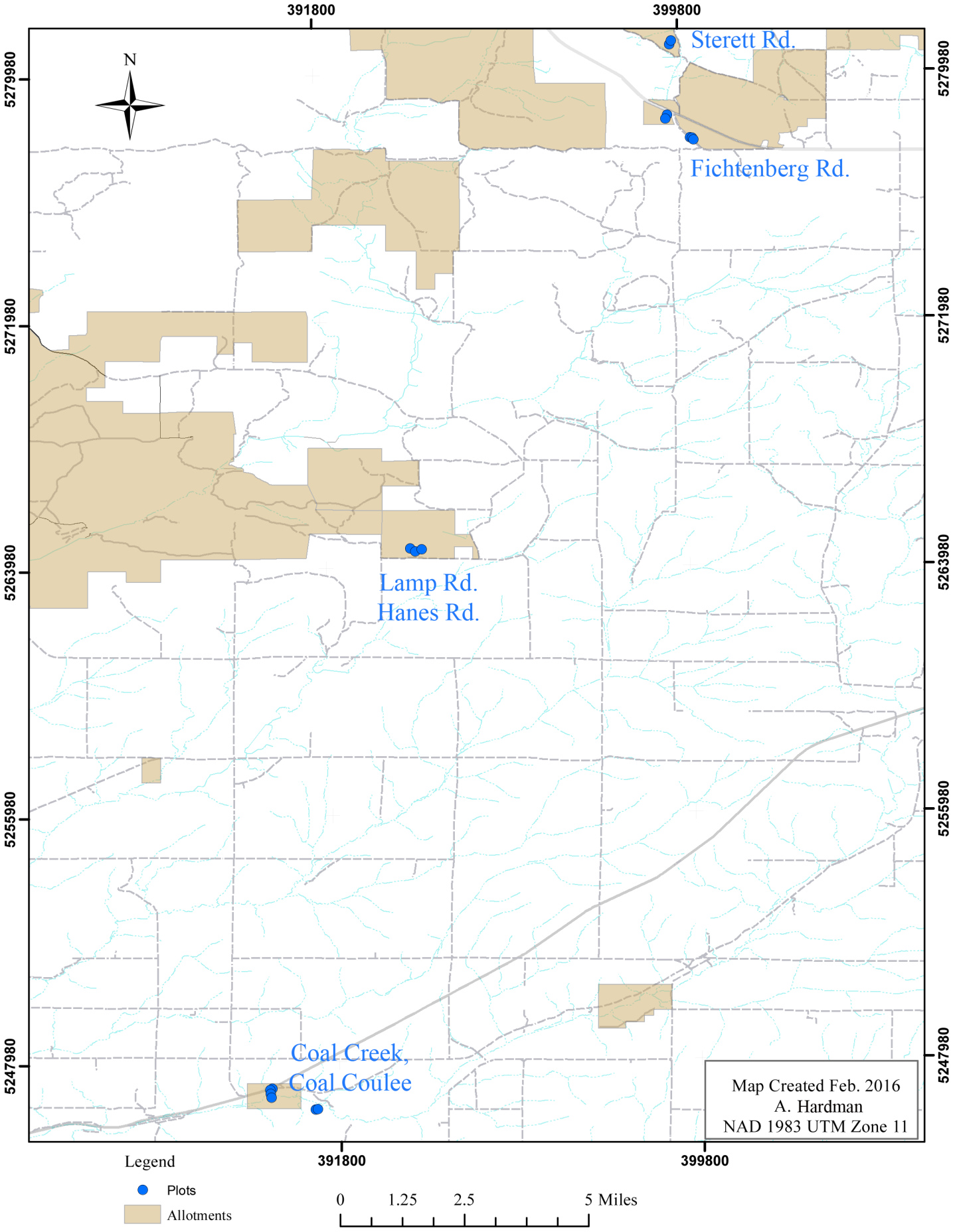
Map E plot locations